Frostick, Lynne E.; McLelland, S.

Ecological Modelling in Hydraulics

Hydrolink

Ecological Modelling

Over the past four years the HYDRALAB III project (http:\\www.hydralab.eu) has tackled many of the difficult issues associated with simulating the interactions of plants and animals with hydraulics and sediment transport in physical models. Eco-hydraulic experimentation is an emerging field for hydraulic facilities and it introduces experimental complexities that are at the forefront of physical modelling research.

Written by:
Lynne E. Frostick and S.J. McLelland, University of Hull, UK
l.e.frostick@hull.ac.uk
s.j.mclelland@hull.ac.uk

In a changing environment there is an urgent need to improve our understanding of both the impact of environmental factors on biota and the impact of biota on their environment. Research on the interaction amongst water flow, morphology, sediment transport and biological processes is therefore essential if we are to improve the management of the natural environment. This is a very new area of research and the challenges associated with it are many. In addition to all of the well established problems of hydraulic experimentation (scale effects, boundary conditions, etc.) there are issues of plant and animal health, response to transfer into the modelling environment and (for animals) ethical considerations. Some of these problems may be circumvented through the use of inert surrogate materials (e.g. plastics, wooden dowling etc) but these may not adequately simulate the live prototypes. Researchers within HYDRALAB have made great strides towards improving the knowledge and understanding of this type of experimentation over the past 4 years as part of the EU Integrated Infrastructure project HYDRALAB III. Through a number of ecologically oriented Access projects, trans-national teams have worked in our laboratories to solve some of the problems of this type of experimentation. We have also worked together to establish guidelines for future researchers. These will be dissimenated as part of a laboratory manual entitled HYDRALAB Users Guide Book to be published by IAHR this year. Some of the main issues for vegetation and animal hydraulic research are outlined briefly below.

Vegetation has a complex effect on flow roughness particularly since it can respond to the flow field itself, hence the roughness due to vegetation is variable due to plants being able to bend and change their shape. Roughness can also be dynamic since the vegetation can move with a wave like motion which introduces a time-varying component to the roughness (e.g. Stephan & Gutknect, 2002). Water velocities under the vegetation canopy can be considerably reduced compared to the flow above, for example Gambi et al. (1990) measured velocity reduction of 2-10 times lower within the canopy compared to upstream of a seagrass bed. This low energy microenvironment can increase suspended sediment deposition and is important for benthic community structure (e.g. Peterson et al., 1984). The hydraulic characteristics of flow within and around vegetation depends upon a number of factors such as the shoot density (e.g. Gambi et al. 1990; Peterson et al., 2004), shoot thickness (Bouma et al. 2005), and patchiness (Folkard, 2005). This means that any inert surrogates used must be very carefully selected and manufactured if they are to the effects of replicate faithfully the interactions between plants and flow.

Figure 1: Measuring the effect of macroalgae on sediment transport and flow structure.

in Hydraulics

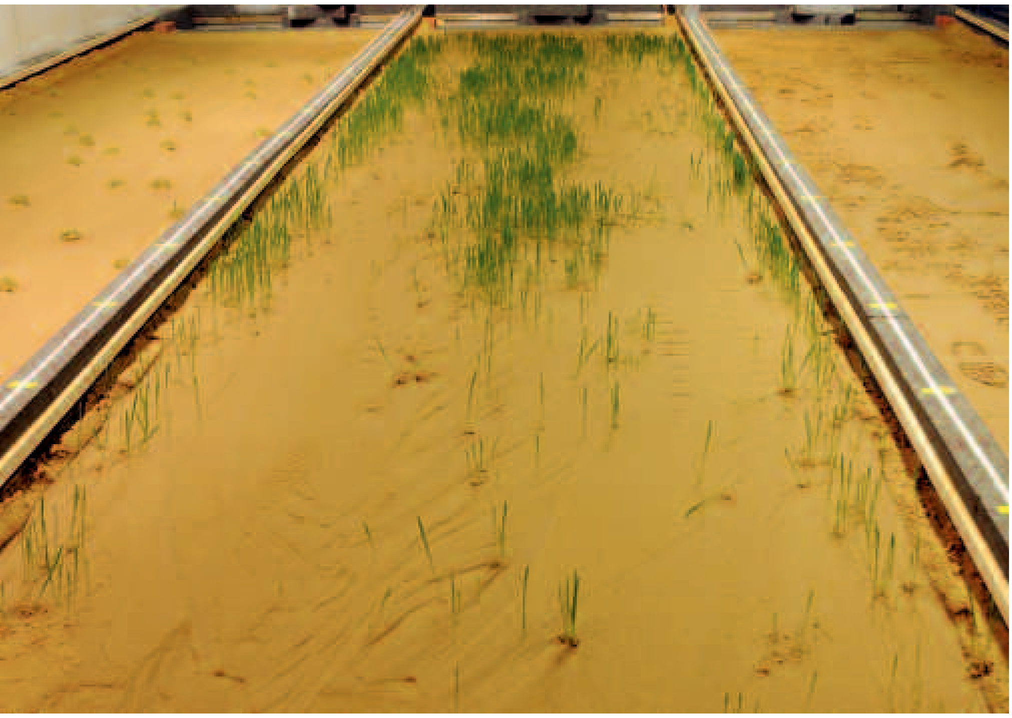


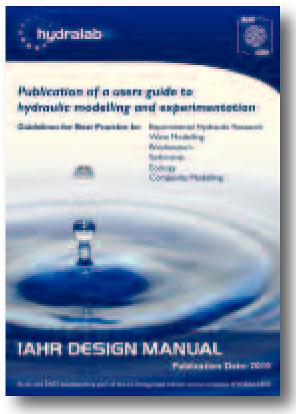
Figure 2: Studying the interaction between vegetation growth and channel development in response to flow events.

Where plants have some flexibility it is essential to ensure that the biomechanical properties of the plant are reproduced in the surrogate that is chosen. Several studies have used strips of different plastic materials (e.g. PVC) to represent blade-like vegetation (e.g. Sand-Jensen, 2003; Folkard, 2005). Folkard (2005) chose a polyethylene sheeting (Decco) as a surrogate that closely replicated the density and modulus of elasticity of natural seagrass plants. However using natural plants is not without problems. They are highly variable and this may make it necessary to carry out replicate experiments. Additional issues that may arise are the fixing of the plants within the flume and the need to maintain their state of health during the experiments. This can be problematic particularly for marine species which require saline water which cannot be used in many hydraulic facilities. Incorporating **animals** into physical hydraulic models is a very new area of research but one that is developing rapidly. An excellent summary of best practice in this field is given in Rice et al. (2010). The interactions between flow and animals are complex since animal response is active not passive, animals can move independently and take action to modify their immediate environment.

A full report on the Hydralab Project was published in Hydrolink 1, 2009 page 6.

In both marine and freshwater systems, benthic organisms depend on hydraulic and sedimentological conditions for the supply of oxygen and food as well as the removal of waste products, therefore flow conditions at the grain/bedform scale and through the water column may be important for animal growth and development as well as the behaviour and spatio-temporal distribution of both individuals and populations or communities. Changes in bed roughness due animals for example in mussel beds can alter the near bed flow structure (e.g. Huttel & Gust, 1992; Friedrichs & Graf, 2009) and the resulting patterns of flow acceleration and deceleration, flow separation and vortex development affect the ability of organisms to capture food (e.g. pathways and residence times for food particles), alter the exchange of gasses and potentially increase solute fluxes in surrounding permeable bed material.

Decisions on whether to use artificial surrogates (casts or plastic replicas) or living organisms will depend on the purpose of the study. Surrogates can only represent passive interactions with flow, not active responses. However experimentation with living organisms is problematic requiring careful maintenance of water quality and temperature which may not be possible in traditional wave tanks and re-circulating flumes. Added to this transfer of animals into the experimental environment may cause shock which modifies behaviour and making robust hydraulic measurements close to small animals is challenging, especially where it is necessary to acquire spatially distributed information at relatively high resolution. For example particle Image Velocimetry (PIV) is widely used for global flow field measurements and provides high-resolution information but seeding materials and laser emissions may have adverse behavioural effects, cause tissue damage or death.



There is a need for greater interaction and collaboration between hydraulic engineers and ecologists. Combining the expertise of researchers from different disciplines is essential to improve the realism of physical models both in terms of their simulation of simple and complex flow and wave environments and the incorporation of plants and animals into those models. Through improved physical modelling that captures both the hydraulic and biological processes, we can develop a better understanding of the interactions between biota and their environment and the effect of the environment on the biota.